

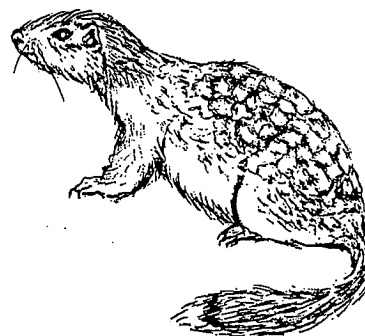
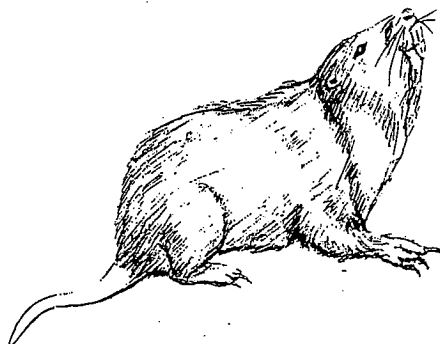


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DWRC
Research Report
No. 11-55-002

Laboratory Efficacy of Cholecalciferol Against Field Rodents



Abstract: We conducted no-choice feeding trials with individually caged animals to evaluate the efficacy of cholecalciferol for killing select pest species of field rodents. Cholecalciferol appeared promising for controlling northern pocket gophers (*Thomomys talpoides*), plains pocket gophers (*Geomys bursarius*), thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*), spotted ground squirrels (*S. spilosoma*), Columbian ground squirrels (*S. columbianus*), Richardson's ground squirrels (*S. richardsonii*), and Polynesian rats (*Rattus exulans*). Low mortality indicated that cholecalciferol may not be effective for controlling black-tailed prairie dogs (*Cynomys ludovicianus*) or Hawaiian populations of Norway rats (*R. norvegicus*) and roof rats (*R. rattus*).

Keywords: Cholecalciferol, ground squirrels, pocket gophers, prairie dogs, Quintox®, rats, rodent control, vitamin D₃

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Laboratory Efficacy of Cholecalciferol Against Field Rodents

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Procedures

Rodents cause extensive damage to agricultural crops throughout the United States, and few rodenticides are available for controlling such depredations. Until recently, strychnine was the most commonly used rodenticide for reducing troublesome populations of pocket gophers, some ground squirrel species, and prairie dogs. However, litigation concerning nontarget hazards compelled the U.S. Environmental Protection Agency (EPA) to withdraw all aboveground uses of this material. Sodium monofluoroacetate (1080) also was used to control certain field rodent pests, but EPA cancelled all rodenticide uses because additional data requirements were not met. Zinc phosphide is the only acute rodenticide still registered in the United States for controlling agricultural rodent pests. Unfortunately, the efficacy of zinc phosphide is variable, and control is often less than complete. Growers need a safe and effective alternative toxicant for reducing agricultural rodent pests.

Cholecalciferol (vitamin D₃) has shown potential as a rodenticide for controlling rock squirrels (*Spermophilus variegatus*) (Beard et al. 1988 a,b), house mice (*Mus musculus*) (Kassa 1978, Marshall 1984, Brown and Marshall 1988, Zaghoul and Zakaria 1986), and rats (*Rattus norvegicus* and *R. rattus*) (Rennison 1974, Marshall 1984, Brown and Marshall 1988). This naturally occurring vitamin is necessary for normal growth and important in the prevention of rickets in humans, but in excessive amounts D₃ is potentially toxic (Vanderveen and Vanderveen 1985). Cholecalciferol is registered under the trade names of Quintox® (Bell Laboratories, Inc.) and Rampage® (Motomco Ltd.) to control rodents in and around buildings and structures. Cholecalciferol-containing rodenticides may be hazardous to dogs that ingest exposed bait (Gunther et al. 1988), but these products are of relatively low toxicity to mallards (*Anas platyrhynchos*) and northern bobwhite (*Colinus virginianus*) (Marshall 1984). Secondary hazards to predators and scavengers appear minimal (Marshall 1984).

In this document, we describe a series of laboratory bioassays to determine the efficacy of cholecalciferol for controlling various species of rodents that are agricultural pests: pocket gophers (*Thomomys talpoides* and *Geomys bursarius*), ground squirrels (*Spermophilus columbianus*, *S. tridecemlineatus*, *S. richardsonii*, and *S. spilosoma*), prairie dogs (*Cynomys ludovicianus*), and wild rats (*Rattus norvegicus*, *R. rattus*, and *R. exulans*).

Procurement and Care of Animals

Pocket Gophers.—We captured plains pocket gophers near Pleasanton, TX, with polyvinyl chloride tube-type traps baited with carrots. Bottle traps baited with carrots and oats were used to capture northern pocket gophers near Nederland and Wellington, CO. We transferred the pocket gophers to the Denver Wildlife Research Center (DWRC) in Denver, where they were dusted with pyrethrum powder, weighed, identified to sex, and housed individually in 40.6- × 24.1- × 18.0-cm stainless steel cages. The animal rooms had an ambient temperature of 21 °C and a light/dark cycle of 12 h/12 h. The pocket gophers were maintained on a diet of carrots, hay cubes, and pelleted rodent laboratory chow for 14 days while they acclimated to laboratory conditions.

Ground Squirrels.—We used Tomahawk® traps baited with barley to capture spotted ground squirrels and thirteen-lined ground squirrels on the eastern plains of Colorado, Richardson's ground squirrels in the North Park area of Colorado, and Columbian ground squirrels near Helena, MT. The ground squirrels were transported to DWRC, dusted with pyrethrum powder, weighed, sexed, and housed individually in 40.6- × 24.1- × 18.0-cm stainless steel cages in rooms with an ambient temperature of 21 °C and a light/dark cycle of 12 h/12 h. The ground squirrels were maintained on a diet of barley, pelleted rodent laboratory chow, and water for 14 days or more before testing.

Black-Tailed Prairie Dogs.—The black-tailed prairie dogs were captured in Adams County, CO, by pouring water and Wisk® soap into burrows and seizing the animals as they emerged. We transported the prairie dogs to DWRC, dusted them with pyrethrum powder, recorded their weight and sex, and housed them individually in 54- × 54- × 40-cm stainless steel cages in rooms with an ambient temperature of 21 °C and a light/dark cycle of 12 h/12 h. We maintained the prairie dogs on an *ad libitum* diet of barley, pelleted rodent laboratory chow, hay cubes, and water for a minimum of 14 days before testing.

Rats.—We used Japanese live traps to capture rats in forested areas, sugarcane fields, and associated noncrop areas on the island of Hawaii. We transported the rats to DWRC's field station in Hilo, HI and recorded the species, sex, and weight of each animal, dusted them with carbaryl powder, and housed them individually in 18- × 18- × 36-cm stainless steel cages. The animal rooms had an ambient temperature of 25 °C and a light/dark cycle of 12 h/12 h. The Norway rats from the continental United States were live-trapped from a captive colony at DWRC and housed individually there in stainless steel cages at 21 °C with a light/dark cycle of 12 h/12 h. All rats were maintained on an *ad libitum* diet of rodent laboratory chow and water for a minimum of 21 days before testing. At the end of quarantine, we weighed animals that appeared healthy and transferred those that met the minimum weight requirement to the test room. Only Norway rats and roof rats weighing >90 g and Polynesian rats weighing >35 g were used for testing.

Prebait Acceptance Tests

We conducted prebait acceptance tests with ground squirrels to ensure that animals used for testing would eat the test bait of steamed rolled-oat groats. We did not prebait any of the other species. At 1600 h on the day before the beginning of each prebait acceptance test, the maintenance food was removed from the cages. At 1700 h on the following day (Day 1), we offered each ground squirrel 15–20 g of prebait in an aluminum dish fastened to the front of the cage with a metal spring. A tray under each cage caught spillage. At 0700 h on Days 2, 3, and 4, we removed the dishes and spillage trays and weighed the remaining prebait and any spillage. At 0700 h on Days 2 and 3, we offered fresh prebait and placed clean spillage trays under the cages. We calculated consumption for each of Days 1–3 as the difference between the amount of prebait offered and that remaining 24 h later, minus any spillage. Any ground squirrels that consumed less than 8 g of prebait over the 3-day prebait acceptance test were excluded from further testing.

Feeding Trials

The general procedures for all species and feeding trials were the same. All were no-choice tests during which individually caged animals were offered an assigned bait in place of their maintenance diet. Trays were placed beneath cages to catch spillage, and water was available *ad libitum*. We offered fresh bait daily and collected uneaten and spilled bait 24 h after it was offered. At the conclusion of each feeding trial, we removed the bait from the cages and returned the maintenance food.

During the feeding trials and for 7 to 27 days posttreatment (depending on the species and test), we checked the animals daily for mortality or signs of toxicosis. We weighed and froze carcasses for later disposal. At the end of the posttreatment observation period, we weighed and sacrificed survivors with carbon dioxide.

We measured changes in the weight of the bait due to moisture loss or gain by placing a bowl of each treatment in the test room at the same time that the bait was offered to the animals, and removing and reweighing it 24 h later. From the results of this calculation, we adjusted the amount of bait consumed by each rodent accordingly. Total consumption for each test was the sum of the daily consumption for each of Days 1–3.

Sample sizes varied among species and treatment groups. We conducted a range-finding test with five plains pocket gophers per group to determine the most appropriate chemical concentrations for this species. For most of the tests, we included 10 or more animals in each group to determine the approximate lowest concentration of cholecalciferol that results in 100-percent mortality. We subsequently conducted additional tests with some species during which we used 15 or 20 animals in each group to define more precisely the lowest concentration needed for 100-percent mortality.

Results and Discussion

Baits

Cholecalciferol-treated steamed rolled-oat groats were used as a bait for all the species. Quintox Rat and Mouse Bait, a commercial pelleted rodenticide (Bell Laboratories, Inc.), was offered to northern pocket gophers and to the three species of rats. We used untreated Royal Rabbit Pellets® (Bay Enterprises, Inc.) as a control bait in the Quintox Rat and Mouse Bait feeding trials with rats. A cholecalciferol-treated ground rodent bait consisting by weight of 65 percent cornmeal, 25 percent steamed rolled oats, 5 percent powdered confectioners sugar, and 5 percent corn oil also was evaluated with Norway rats and roof rats.

An electric kitchen mixer was used to combine the baits with the appropriate amount of cholecalciferol. The technical material used for the pocket gophers, ground squirrels, and prairie dogs was Quintox concentrate (7.5 percent cholecalciferol liquid concentrate, Bell Laboratories, Inc.). The rat baits were formulated either with Quintox concentrate or with crystalline cholecalciferol (Sigma Chemical Company) and 2.0 percent Alcolec-S® (a lecithin oil, American Lecithin, Inc.). We dissolved the crystalline cholecalciferol in a 50-50 mixture of ethanol and acetone before adding it to the oats and drying the bait under a fume hood. The treated oats were then slurry-coated with Alcolec-S.

We offered each pocket gopher and prairie dog 12 g of its assigned bait per day, and each ground squirrel 10-30 g of bait per day (depending on the test). Norway and roof rats received 20 g of bait per animal per day, and Polynesian rats received 10 g per animal per day. Norway rats from the continental United States were offered 30 g per animal per day.

Motomco Ltd., of Madison, WI, analyzed the percent cholecalciferol in each bait using high-pressure liquid chromatography. All concentrations reported herein are those determined by assay.

Northern Pocket Gophers

Mortality of northern pocket gophers offered oat groats was 100 percent at most concentrations at or above 0.0028 percent (table 1). Mean days to death ranged from 4.3 to 6.3. Bait consumption for all groups generally was greatest on Day 1 and declined sharply on subsequent days. Average amount of bait consumption decreased with increasing concentration of cholecalciferol, although the milligrams cholecalciferol ingested per kilogram of body weight increased with concentration. Three of the four survivors offered Quintox Rat and Mouse Bait were noneaters. These tests indicate that under no-choice conditions, oat groats treated with cholecalciferol at concentrations far below 0.075 percent, the level registered for commercial baits, may be effective for controlling northern pocket gophers. Additional tests are needed to evaluate this bait for controlling northern pocket gophers under field conditions.

Plains Pocket Gophers

Mortality ranged from 40 percent at 0.009 percent concentration up to 100 percent in 9 other treatment groups (table 2). Mean days to death ranged from 4.4 to 8.0. Consumption generally declined with increasing concentration, but milligrams of cholecalciferol ingested per kilogram of body weight was relatively stable among the groups. Survivorship was greatest in those groups that, on average, ingested the least amount of cholecalciferol.

Thirteen-Lined Ground Squirrels

All thirteen-lined ground squirrels exposed to cholecalciferol-treated bait died (table 3). Mean days to death varied from 4.9 to 6.1, and no mortalities occurred until at least 3 days after initial exposure to the bait. Average consumption declined with increasing concentration of cholecalciferol.

These data indicate that cholecalciferol-treated oats are an effective bait for killing thirteen-lined ground squirrels under no-choice conditions. Additional laboratory tests should be conducted to identify the minimum concentration needed to kill 100 percent of the exposed animals when the quantity of bait is restricted to 1 tablespoon (11-12 g), a customary amount for placing in individual burrows. Cholecalciferol-treated oats should be evaluated for controlling thirteen-lined ground squirrels under field conditions.

Spotted Ground Squirrels

Nine of 10 spotted ground squirrels offered 0.094 percent cholecalciferol-treated oat groats and all 3 spotted ground squirrels offered 0.487 percent cholecalciferol-treated oats died (table 3). Average days to death were 8.2 for the former group and 16.0 for the latter group. Additional laboratory tests should be conducted to determine the lowest concentration of cholecalciferol that kills 100 percent of spotted ground squirrels.

Columbian Ground Squirrels

Mortality of Columbian ground squirrels was 80 percent or better in the four groups offered cholecalciferol-treated oats (table 3). Mean days to death varied from 4.5 to 5.7. One of the survivors in the 0.674 percent group consumed only 0.41 g of bait. The 100-percent mortality in the 0.094 percent group indicates that grain baits treated at about the concentration (0.075 percent) registered for commensal rodent control might be effective for this species. However, more testing is needed to confirm this. Laboratory tests should be conducted to determine the minimum concentration needed to produce 100-percent mortality when the quantity of bait simulates the field application rate of 1 tablespoon (11–12 g) or less.

Richardson's Ground Squirrels

Mortality of Richardson's ground squirrels ranged from 89 to 100 percent among the three groups (table 3). Average days to death ranged from 5.4 to 6.7. One squirrel in the 0.568 percent group escaped during the test and was not included in the results. The lone survivors in the 0.094 percent and 0.568 percent groups each consumed only 8.7 g and 0.7 g, respectively, of bait.

Black-Tailed Prairie Dogs

Mortality ranged from 0 to 40 percent in the 6 groups tested (table 4). Mean days to death ranged from 5 to 14. Average overall consumption generally declined with increasing concentration of cholecalciferol, although the average milligrams of cholecalciferol ingested per kilogram of body weight was similar among the groups. The low mortality in all groups suggests that cholecalciferol-treated oat groats, at the concentrations explored, are not an effective bait for controlling black-tailed prairie dogs.

Norway Rats

Mortality of Norway rats offered oat groats treated with the Quintox concentrate ranged from 1 out of 10 in the 0.102 percent group to 8 out of 10 in 0.335 percent group (table 5). Mean days to death varied from 4.8 to 11.2. Average consumption declined with increasing concentration of cholecalciferol. Average milligrams of cholecalciferol ingested per kilogram of body weight was highest in the 0.335 percent group, the group with the highest mortality.

The oat-groat baits with a higher concentration of toxicant were excessively oily. That characteristic may have reduced their palatability or affected their absorption in the alimentary canal. The 7.5 percent concentrate used to formulate the baits was developed by Bell Laboratories, Inc., for preparing their 0.075 percent Quintox bait, and it may not have been suitable for mixing the higher concentration baits evaluated in this study. Additional testing is needed to evaluate alternative technical materials for formulating cholecalciferol baits in concentrations above 0.075 percent.

The mortality of Norway rats offered oats treated with crystalline cholecalciferol was slightly higher than that of rats in the two lowest Quintox concentrate groups (table 5), suggesting that the crystalline material may be more effective for baits in higher concentrations.

We evaluated the ground rodent diet to determine whether efficacy would improve with a bait that presumably would absorb more of the cholecalciferol concentrate. Mortality with the ground rodent diet varied from 2 of 10 to 7 of 10 among the groups and was similar to that with the oat-groat bait (table 5). As with the oat-groat bait, consumption of the rodent ground diet declined with increasing concentration of cholecalciferol.

Only 4 of 10 Hawaiian Norway rats offered Quintox Rat and Mouse Bait died, compared to 100-percent mortality for the 20 wild Norway rats tested from the continental United States (table 5). Average consumption in all groups of surviving Norway rats exceeded 43.6 mg/kg, the purported LD_{50} for this species (Marshall 1984). Our results with Hawaiian Norway rats contrast with those of other investigators. Greaves et al. (1974) observed 100-percent mortality of wild Norway rats captured in Great Britain and fed on 0.1 percent calciferol (vitamin D_2) for 2 days. Bai et al. (1978) and Marshall (1984) offered 0.1 percent calciferol and 0.075 percent cholecalciferol, respectively, to laboratory (Wistar) rats and also reported 100-percent mortality. More study is needed to evaluate differences among populations of Norway rats in the efficacy of cholecalciferol.

Roof Rats

Mortality of roof rats offered oats treated with Quintox technical material ranged from 0 out of 10 in the 0.055 percent group to only 6 out of 10 in the 0.102 percent group (table 6). Mean days to death varied from 6.0 to 12.8 among the five treatment groups. Average consumption declined with increasing concentration of cholecalciferol. Average milligrams of cholecalciferol ingested per kilogram of body weight was highest in the groups with the highest mortality.

Seven out of 10 roof rats offered oats prepared with crystalline cholecalciferol died; the average days to death was 10.6 (table 6). Consumption was similar to that of roof rats in the two lowest treatment groups offered oats treated with Quintox technical material.

Mortality of roof rats offered the ground rodent diet varied from 3 of 10 to 5 of 10 animals tested, and mean days to death varied from 10.6 to 15.0 (table 6).

Only 3 out of 10 roof rats offered the Quintox Rat and Mouse Bait died (table 6). Days to death ranged from 12 to 15.

Bai et al. (1978) conducted 7-day laboratory efficacy tests with roof rats trapped in the wild, and reported 90-percent mortality in groups offered bait with 0.05 percent and 0.075 percent calciferol, and 100-percent mortality in a group offered bait with 0.10 percent calciferol. The higher mortality during these trials than during our tests may be due to (1) the use of vitamin D₂ instead of vitamin D₃, (2) the use of a longer test period, or (3) the generally greater amounts of toxicant ingested per kilogram of body weight.

Polynesian Rats

We initially used 10 Polynesian rats per group to evaluate Quintox concentrate applied to oat groats, but we later expanded this sample size to 20 animals per group. During the initial tests with the smaller sample size, 6 of 10 Polynesian rats in the 0.055 percent group and all 10 rats in each of the 0.102 percent and 0.162 percent groups died (table 7). Mean days to death varied from 8.8 to 9.1. Total consumption was similar for the two lower groups and was about twice that of the highest group. The amount of cholecalciferol ingested per kilogram of body weight was similar between the two higher groups, each of which ingested about 40–50 percent more cholecalciferol than did rats in the lowest group.

During the expanded tests, the number of Polynesian rats that died/number of rats tested was 0/20 at 0 percent (control group), 17/20 at 0.028 percent, 19/20 at 0.077 percent, and 18/20 at 0.100 percent (table 7). Mean days to death varied from 9.1 to 10.1. Mean amount of cholecalciferol ingested per kilogram of body weight was almost twice as high in each of the higher cholecalciferol groups than in the 0.028 percent group.

Eight of 10 Polynesian rats offered oat groats treated with the crystalline cholecalciferol died, with a mean days to death of 10.4 (table 7). This mortality rate was comparable to that of the groups offered bait treated with Quintox concentrate at less than 0.1 percent.

Seven of 10 Polynesian rats offered the commercial rodenticide Quintox died (table 7).

These tests indicate that cholecalciferol may be an effective field rodenticide for controlling populations of Polynesian rats.

Conclusion

Cholecalciferol applied to rolled oat groats appears promising for controlling northern pocket gophers, plains pocket gophers, thirteen-lined ground squirrels, spotted ground squirrels, Columbian ground squirrels, Richardson's ground squirrels, and Polynesian rats. Cholecalciferol does not appear effective for controlling black-tailed prairie dogs. Hawaiian populations of Norway rats and roof rats, for reasons unknown to us, were not found to be very susceptible to cholecalciferol baits.

Additional laboratory tests are needed to identify the minimum concentration that controls plains pocket gophers and each of the four species of ground squirrels. Field studies should be conducted to evaluate cholecalciferol for controlling northern pocket gophers and Polynesian rats.

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Table 1—Mean consumption (SE) of cholecalciferol-treated oat groats and mortality of northern pocket gophers (*Thomomys talpoides*) during no-choice feeding trials

Concentration of active ingredient	Length of test	Numbers of males and females	Mean initial body weight	Consumption				Cholecalciferol ingested		No. died/no. tested	Days to death	
				Day 1	Total							
Percent	Days		g SE	g SE	g SE	g SE	g SE	Mean mg/kg body weight			Mean	Range
								Survived	Died			
0.000	3	4M,11F	131 4.5	4.9 0.9	12.5 1.9			—	—	0/15	—	—
0.002	3	4M,11F	133 5.3	2.8 0.4	5.8 0.7			0.9	0.8	12/15	6.3	4–12
0.0028	3	4M,6F	128 5.2	3.1 0.6	4.9 1.0			0.5	1.4	7/10	5.4	4–6
0.0028	3	3M,7F	130 8.4	2.8 0.5	2.9 0.5			—	6.9	10/10	4.3	3–6
0.009	3	3M,7F	128 8.4	2.9 0.9	3.3 0.6			—	2.6	10/10	4.3	3–8
0.0383	3	6M,9F	132 5.0	2.5 0.4	2.7 0.3			—	7.9	15/15	4.8	3–6
0.043	3	2M,8F	117 2.8	4.0 0.7	4.2 0.6			—	15.2	10/10	5.2	3–7
0.063	1	10M,10F	123 3.1	3.5 0.3	3.5 0.3			8.1	18.6	19/20	6.0	4–10
0.068	3	4M,6F	109 4.4	3.5 0.5	3.9 0.6			—	24.5	10/10	5.9	5–7
0.068	1	2M,8F	125 6.8	3.1 0.3	3.1 0.3			—	17.0	10/10	6.3	4–9
0.0682	3	5M,10F	136 4.8	1.5 0.6	1.9 0.7			—	10.1	15/15	5.3	4–7
0.106	3	7M,3F	112 4.8	2.4 0.5	2.5 0.5			1.3	25.4	9/10	5.3	3–7
0.075	3	6M,4F	109 4.5	1.1 0.4	1.4 0.4			4.7	12.2	6/10	6.3	5–9

¹Quintox® Rat and Mouse Bait, which we did not analyze to verify its concentration of cholecalciferol.

Table 2—Mean consumption (SE) of cholecalciferol-treated oat groats and mortality of plains pocket gophers (*Geomys bursarius*) during 3-day, no-choice feeding trials

Concentration of active ingredient	Numbers of males and females	Mean initial body weight	Consumption				Cholecalciferol ingested		No. died/no. tested	Days to death	
			Day 1	Total							
Percent		g SE	g SE	g SE	g SE	g SE	g SE	Mean mg/kg body weight		Mean	Range
								Survived	Died		
0.009	4M,1F	203 14.1	0.9 0.8	4.0 0.8				1.7	1.9	2/5	7.0 7–7
0.015	1M,3F	147 14.2	3.5 1.2	7.8 1.1				10.3	7.8	4/5	7.0 7–7
0.015	5F	146 9.8	2.2 1.0	7.1 1.7				—	7.6	5/5	4.8 4–6
0.015	3M,6F	164 11.7	1.0 0.5	2.4 1.1				0.1	4.2	5/9	7.0 6–8
0.024	3M,2F	180 21.4	2.7 0.7	8.3 1.7				—	11.4	5/5	7.0 7–7
0.028	1M,4F	159 15.4	3.2 1.1	4.8 0.7				—	8.8	5/5	5.6 3–9
0.035	5M	193 22.9	1.5 1.0	5.1 1.8				13.8	9.2	3/5	8.0 6–13
0.041	5M,5F	153 7.5	1.5 0.8	3.5 1.1				1.4	20.0	8/10	7.0 4–14
0.043	2M,3F	176 21.3	2.3 1.0	4.6 1.6				<0.1	15.4	4/5	6.2 5–7
0.054	3M,2F	201 15.2	1.1 0.6	1.6 0.6				<0.1	5.3	4/5	5.7 5–7
0.058	3M,7F	154 7.1	0.4 0.2	1.9 0.9				10.0	4.8	7/10	5.3 4–7
0.061	1M,4F	151 6.3	2.5 0.9	4.0 0.9				—	15.7	5/5	5.2 4–6
0.070	5M,4F	165 11.7	0.2 0.2	0.5 0.3				0.2	2.7	6/9	7.5 5–17
0.070	3M,7F	154 7.2	0.7 0.3	2.4 0.5				—	13.5	10/10	7.2 5–15
0.083	3M,2F	181 13.0	2.0 0.6	2.2 0.7				—	10.7	5/5	6.6 5–8
0.176	4M,6F	160 9.6	0.5 0.3	1.5 0.6				1.5	23.0	7/10	6.0 5–8
0.272	1M,4F	158 15.2	2.0 0.6	2.1 0.6				—	36.9	5/5	4.8 4–5
0.657	2M,3F	149 7.4	1.1 0.4	1.2 0.4				—	53.7	5/5	4.4 2–6
0.657	2M,8F	150 7.0	0.3 0.1	0.4 0.2				—	17.6	10/10	7.4 3–16

Table 3—Mean consumption (SE) of cholecalciferol-treated oat groats and mortality of ground squirrels during no-choice feeding trials

Concentration of active ingredient	Length of test	Numbers of males and females	Mean initial body weight	Consumption		Cholecalciferol ingested		No. died/no. tested	Days to death
				Day 1	Total				
Percent	Days		g SE	g SE	g SE	Mean mg/kg body weight			
						Survived	Died		Mean Range
<i>Spermophilus tridecemlineatus</i>									
0.094	3	6M,4F	141 5.4	10.7 0.8	17.3 1.4	—	114.3	10/10	5.7 4–7
0.487	3	5M,5F	137 11.5	4.1 0.2	6.3 0.6	—	224.8	10/10	4.9 4–8
0.568	1	1M,8F	167 10.2	3.3 0.5	3.3 0.5	—	111.8	9/9	6.1 3–11
<i>Spermophilus spilosoma</i>									
0.094	3	7M,3F	142 7.4	9.7 0.3	18.9 1.4	169.61	23.6	9/10	8.2 3–15
0.487	1	2M,1F	188 14.7	4.2 1.9	4.2 1.9	—	102.1	3/3	16.0 14–18
<i>Spermophilus columbianus</i>									
0.094	3	5M,5F	572 25.3	27.6 1.7	61.0 6.1	—	98.5	10/10	4.5 2–6
0.487	3	5M,5F	614 34.7	6.1 0.9	11.1 2.2	12.9	90.7	9/10	5.3 5–6
0.568	1	5M,7F	497 39.4	5.0 0.6	5.0 0.6	—	60.8	12/12	5.7 4–7
0.674	1	5M,5F	526 26.7	2.9 0.7	2.9 0.7	16.6	43.0	8/10	5.1 5–6
<i>Spermophilus richardsonii</i>									
0.094	3	5M,5F	315 14.6	16.8 1.1	27.1 2.9	36.7	84.2	9/10	5.8 4–7
0.487	3	5M,5F	356 23.9	3.7 0.1	7.0 0.9	—	100.9	10/10	6.7 5–11
0.568	1	5M,4F	301 18.0	7.6 1.1	7.6 1.1	16.5	160.1	8/9	5.4 4–7

Table 4—Mean consumption (SE) of cholecalciferol-treated oat groats and mortality of black-tailed prairie dogs (*Cynomys ludovicianus*) during no-choice feeding trials

Concentration of active ingredient	Length of test	Numbers of males and females	Mean initial body weight	Consumption		Cholecalciferol ingested		No. died/no. tested	Days to death
				Day 1	Total				
Percent	Days		g SE	g SE	g SE	Mean mg/kg body weight			
						Survived	Died		Mean Range
0.108	3	5M,5F	867 42.8	10.1 1.2	19.1 2.5	23.4	25.9	1/10	5.0 —
0.176	3	2M,6F	1,080 46.9	9.5 1.3	12.7 1.3	29.1	37.0	3/8	10.0 6–14
0.202	3	5M	1,363 96.1	7.2 1.3	17.5 1.4	24.5	29.0	2/5	14.0 12–16
0.487	3	2M,5F	974 50.7	2.6 1.1	4.3 1.1	23.4	—	0/8	— —
0.732	1	5M,5F	906 43.2	1.9 0.6	1.9 0.6	11.1	73.0	1/10	5.0 —
0.732	3	4M,4F	936 32.0	2.1 1.3	3.4 1.2	27.9	—	0/8	— —

Table 5—Mean consumption (SE) of various cholecalciferol-treated baits and mortality of Norway rats (*Rattus norvegicus*) during 3-day no-choice feeding trials

Concentration of active ingredient ¹	Mean initial body weight		Consumption				Cholecalciferol ingested		No. died/no. tested ²	Days to death	
			Day 1	Total							
Percent	g	SE	g	SE	g	SE	Mean mg/kg body weight			Mean	Range
							Survived	Died			
Oat groats³											
0.055	189	15.2	8.3	1.1	22.5	1.4	61.7	72.9	5/10	11.2	6–25
0.102	186	16.6	9.0	1.2	15.5	1.6	90.7	102.2	1/10	5.0	—
0.162	195	22.5	6.8	1.2	10.1	1.1	77.6	91.6	7/10	7.6	5–12
0.335	208	16.0	5.5	0.8	7.7	1.1	114.4	133.9	8/10	8.0	5–14
0.554	198	13.5	1.3	0.4	2.7	0.3	91.1	67.2	5/10	7.0	5–9
0.770	198	14.6	1.2	0.3	2.2	0.3	104.6	72.7	4/10	4.8	4–5
Oat groats⁴											
0.074	186	7.3	9.3	1.7	29.5	1.3	116.0	118.7	8/10	11.0	7–22
0.000	178	12.7	11.9	1.0	38.4	2.3	0.0	—	0/10	—	—
Ground rodent diet⁵											
0.079	192	13.1	9.5	1.5	16.0	2.4	53.5	68.7	7/10	7.6	4–12
0.302	183	11.1	1.8	0.4	3.7	0.4	53.7	68.9	6/10	8.8	5–14
0.837	184	14.1	0.3	0.1	1.0	0.1	56.8	25.4	2/10	9.0	8–10
Commercial bait											
⁶ 0.091	205	15.3	11.0	0.8	13.6	1.5	61.6	57.5	4/10	12.0	7–25
⁷ 0.000	215	11.9	3.5	0.6	23.4	1.7	0.0	—	0/10	—	—
^{6,8} 0.086	250	15.0	13.4	0.9	16.1	0.9	—	56.7	20/20	9.1	3–14

¹Baits were assayed by high-pressure liquid chromatography.

²Equal numbers of males and females were tested in each group.

³Baits were formulated with technical cholecalciferol (9.18% AI) supplied by Bell Laboratories, Inc.

⁴Baits were formulated with 2% Alcolec-S (an adhesive) and crystalline cholecalciferol (98.9% AI) purchased from Sigma Chemical Co.

⁵Diet consisted by weight of 65% cornmeal, 25% steamed rolled oats, 5% powdered confectioners sugar, and 5% corn oil. It was treated with technical cholecalciferol (9.18% AI) supplied by Bell Laboratories, Inc.

⁶Quintox® Rat and Mouse Bait.

⁷Royal Rabbit Pellets®.

⁸Rats in this group were taken from a captive colony of wild rats in Denver, CO. Rats in all other groups were captured in Hawaii.

Table 6—Mean consumption (SE) of various cholecalciferol-treated baits and mortality of roof rats (*Rattus rattus*) during 3-day no-choice feeding trials

Concen- tration of active ingredient ¹	Mean initial body weight		Consumption				Cholecalciferol ingested		No. died/ no. tested ²	Days to death	
			Day 1	Total							
Percent	g	SE	g	SE	g	SE	Mean mg/kg body weight			Mean	Range
							Survived	Died			
Oat groats ³											
0.055	176	14.5	11.6	1.5	25.6	3.0	79.5	—	0/10	—	—
0.102	178	17.7	8.4	0.9	14.6	2.2	58.6	108.4	6/10	12.8	6–21
0.162	168	14.6	5.9	0.9	8.5	0.6	80.3	97.9	5/10	12.0	5–26
0.335	180	10.4	2.8	0.6	3.6	0.4	68.2	79.1	3/10	6.0	6–6
0.554	175	10.4	2.1	0.5	2.5	0.5	74.2	91.0	5/10	9.8	3–28
Oat groats ⁴											
0.074	179	8.4	11.0	1.1	21.6	1.9	77.2	94.6	7/10	10.6	6–18
0.000	176	9.1	10.3	1.5	35.4	2.7	0.0	—	0/10	—	—
Ground rodent diet ⁵											
0.074	157	10.4	5.2	1.3	8.0	1.4	38.3	40.6	3/10	15.0	13–16
0.320	159	9.4	1.9	0.6	3.4	0.6	33.2	113.2	5/10	10.6	4–19
0.824	166	10.0	1.1	0.3	1.9	0.3	103.8	91.6	4/10	12.0	8–17
Commercial bait											
⁶ 0.091	179	8.8	7.6	1.0	8.6	0.8	39.7	53.9	3/10	13.7	12–15
⁷ 0.000	178	9.1	6.8	0.5	28.5	1.6	0.0	—	0/10	—	—

Note: Footnotes 1–7 match the same numbers in table 5.

Table 7—Mean consumption (SE) of various cholecalciferol-treated baits and mortality of Polynesian rats (*Rattus exulans*) during 3-day no-choice feeding trials

Concen- tration of active ingredient ¹	Mean initial body weight		Consumption				Cholecalciferol ingested		No. died/ no. tested ²	Days to death	
			Day 1	Total							
Percent	<i>g</i>	<i>SE</i>	<i>g</i>	<i>SE</i>	<i>g</i>	<i>SE</i>	Mean mg/kg body weight			<i>Mean</i>	<i>Range</i>
							Survived	Died			
Oats ³											
0.055	69	6.8	4.3	0.6	14.8	1.0	117.8	131.6	6/10	8.8	5–13
0.102	74	8.1	4.4	0.6	13.2	1.0	—	190.2	10/10	9.1	6–16
0.162	70	6.9	1.9	0.5	7.3	0.8	—	173.3	10/10	9.1	6–17
0.000	70	3.8	4.1	0.3	14.0	0.8	0.0	—	0/20	—	—
0.028	71	3.6	3.9	0.4	12.1	0.7	40.8	49.7	17/20	10.1	5–18
0.077	71	4.0	3.3	0.5	10.8	0.8	121.2	119.8	19/20	9.8	6–15
0.100	71	4.4	3.3	0.4	8.7	0.6	127.9	122.3	18/20	9.1	6–22
Oats ⁴											
0.074	76	4.7	2.7	0.9	11.8	2.1	44.1	127.1	8/10	10.4	8–16
0.000	74	5.2	3.5	1.0	14.0	2.4	0.0	—	0/10	—	—
Commercial bait											
⁵ 0.091	64	5.1	4.9	0.4	7.5	0.6	114.3	105.0	7/10	8.1	7–9
⁶ 0.000	63	5.0	2.5	0.3	12.0	1.0	0.0	—	0/10	—	—

Note: Footnotes 1–4 match the same numbers in table 5.
Footnotes 5 and 6 match 6 and 7 in table 5.